Muon ID Study in the Forward Region at ePIC for EIC 2nd Detector

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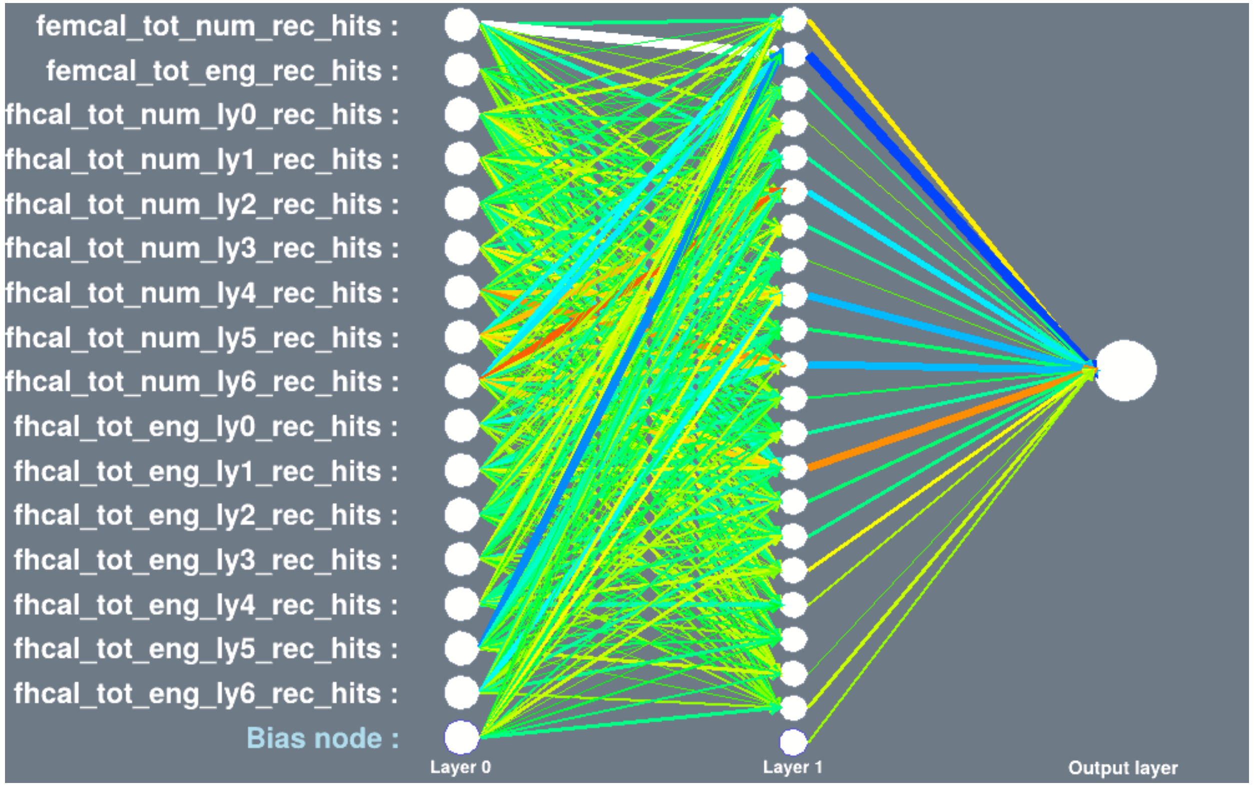
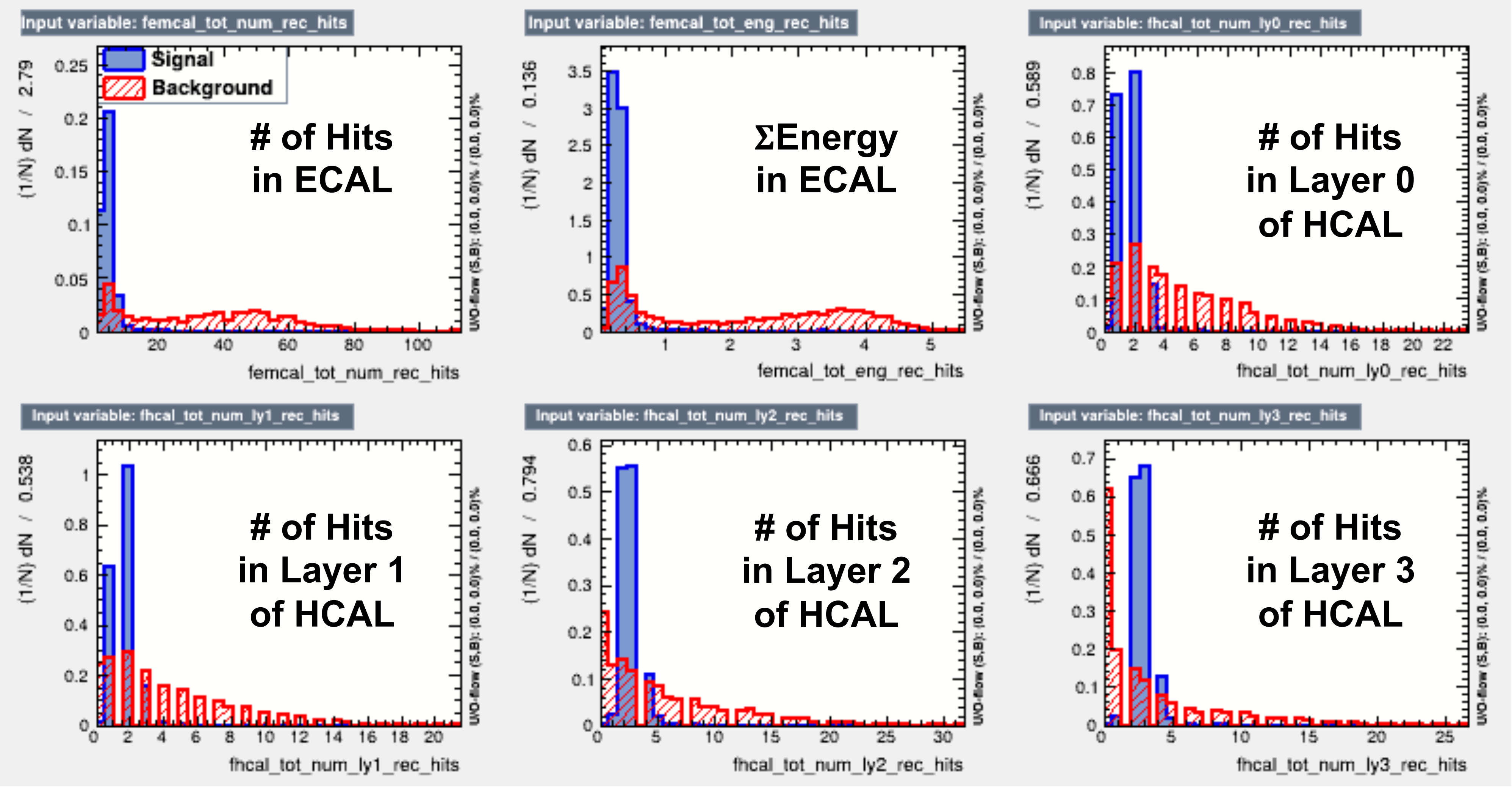
What's New

- Added another input: # of hits from each individual layer of fHCAL
- Updated mis-ID efficiency and rate according to cross section



Input Distribution for 5 GeV μ^+ and π^+



Figures are normalized to show 1/N*dN/dx. So integral of histogram equals to 1.

Brookhaven National Laboratory

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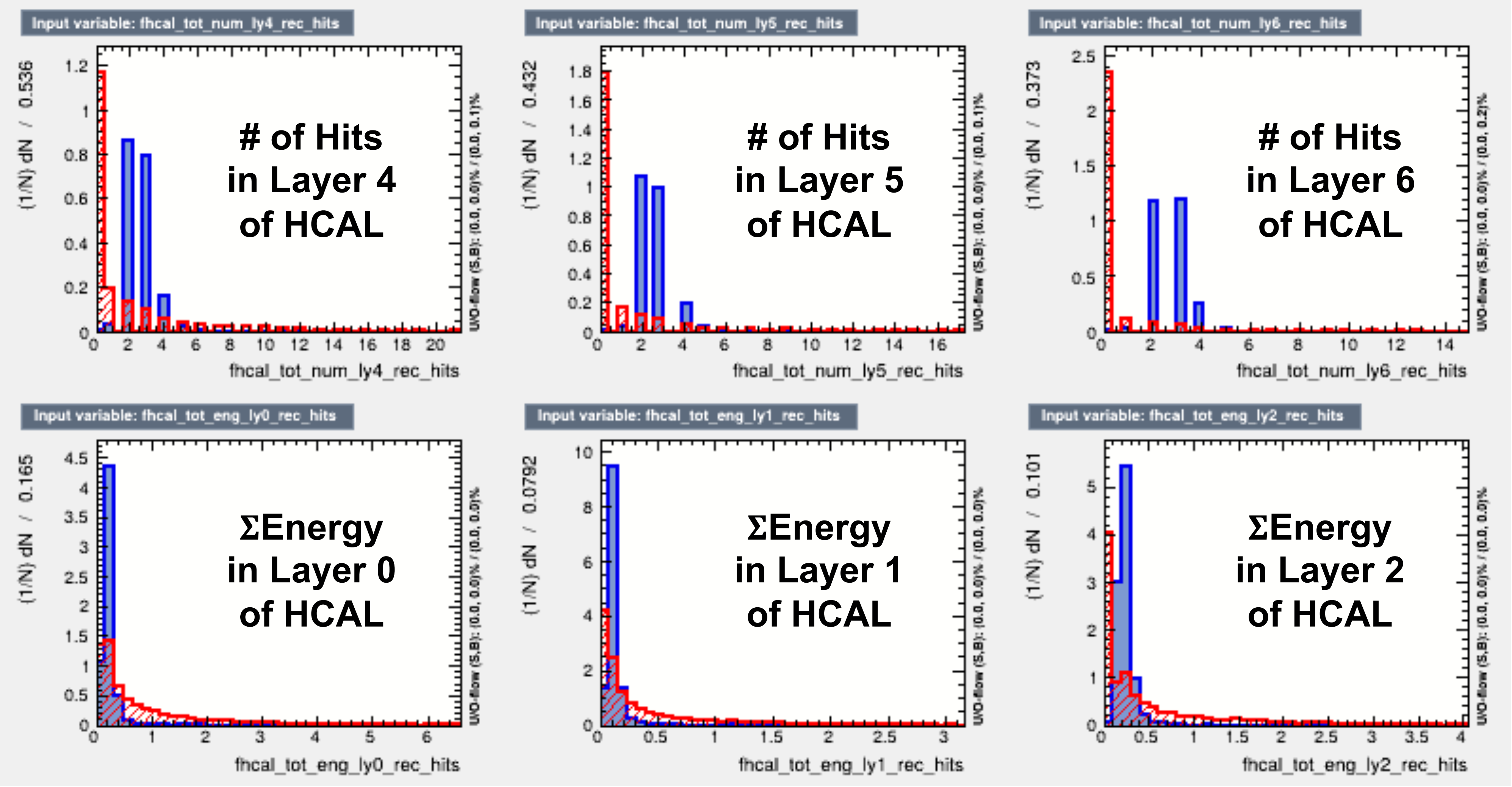

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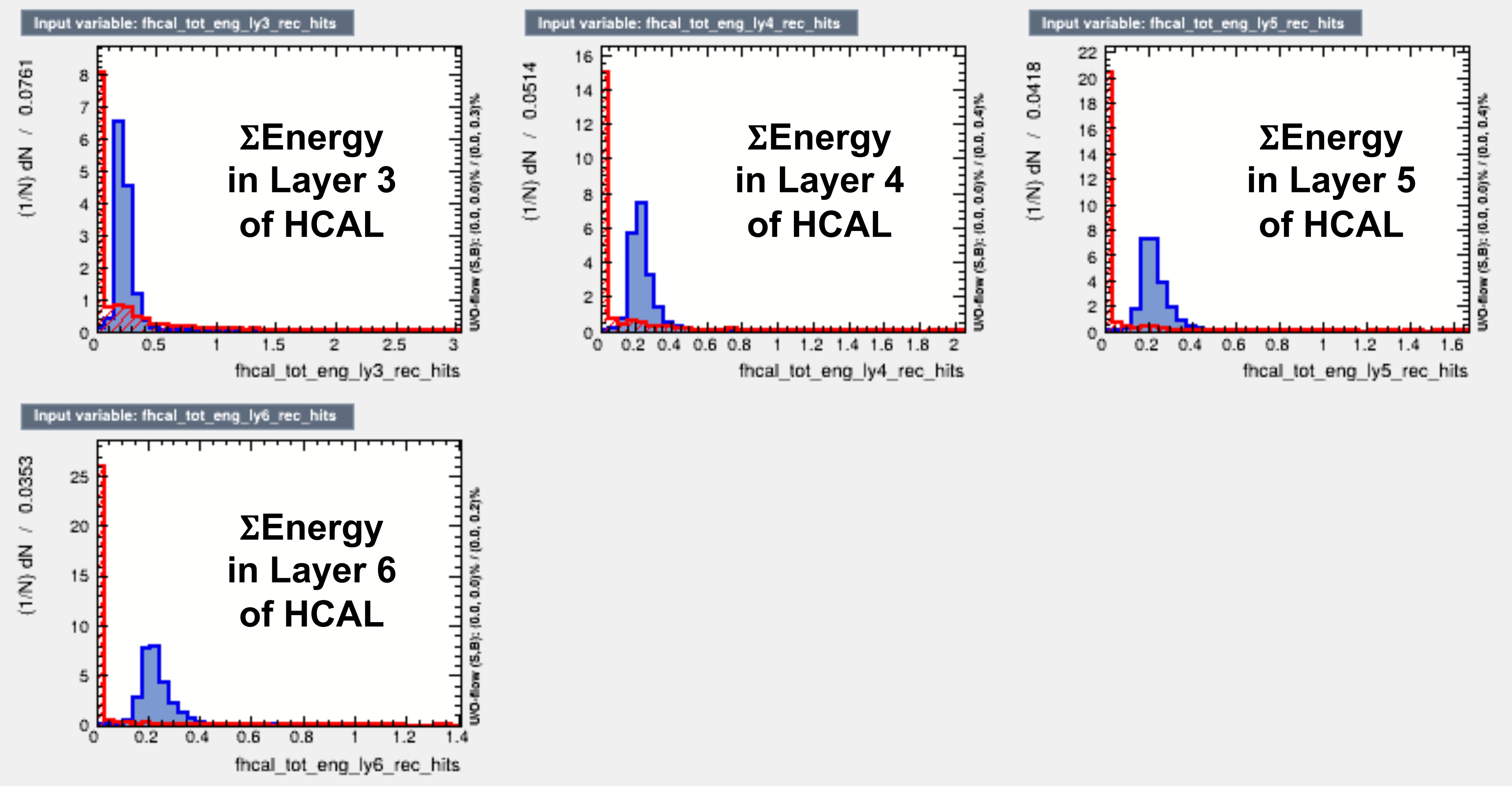

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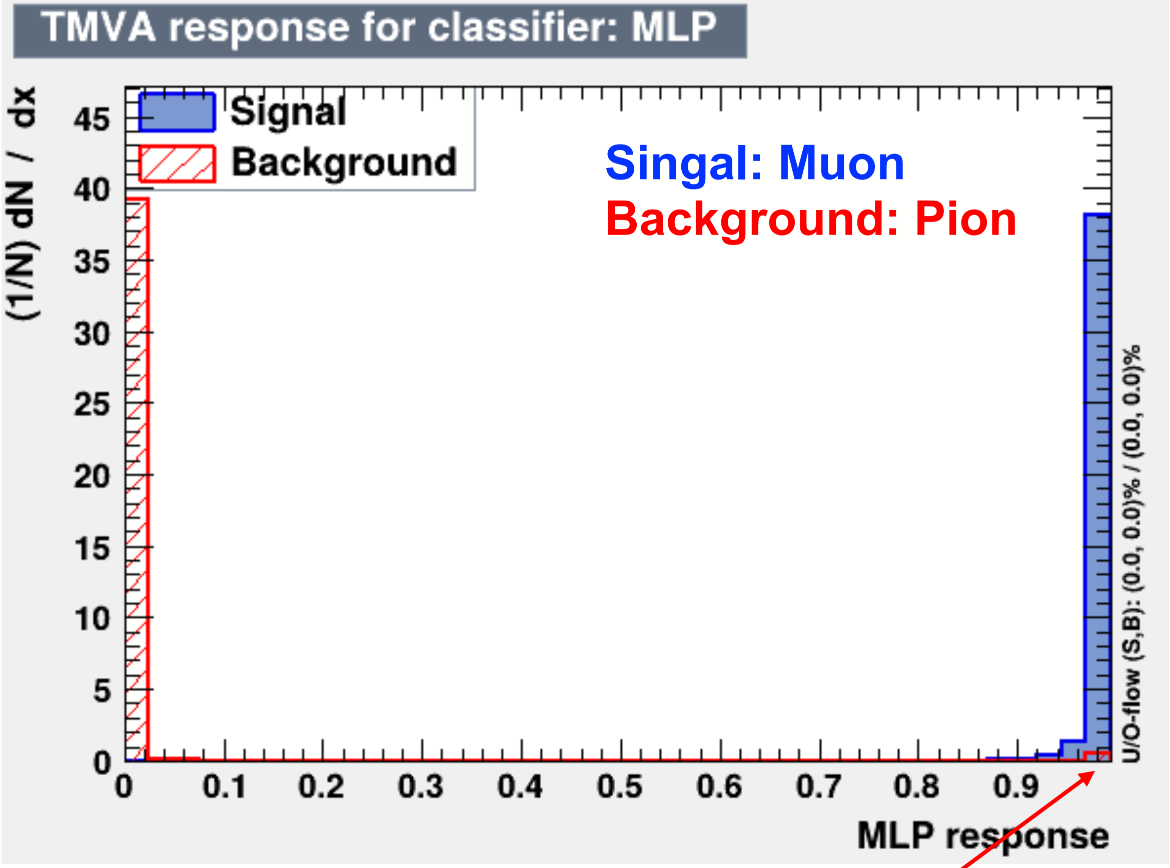
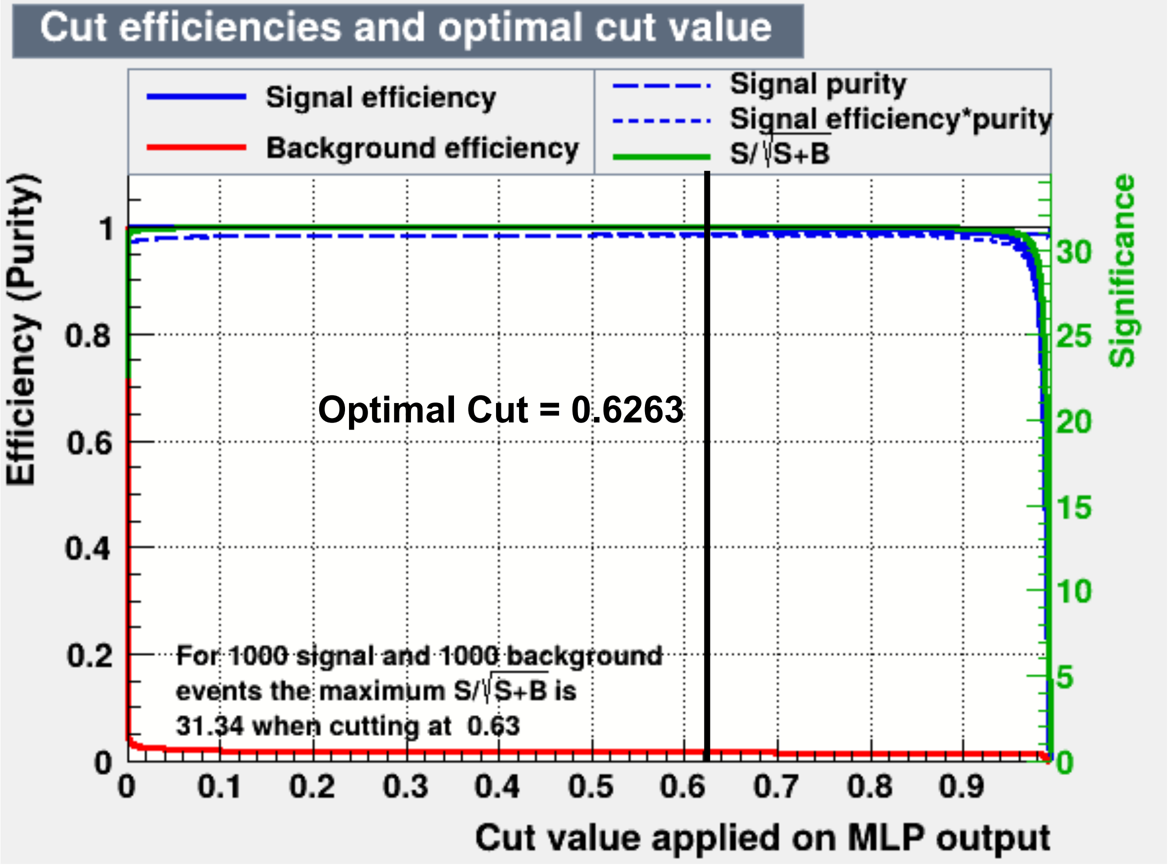
Singal/Background Efficiency for 5 GeV



MIP-like background (pions)



$\varepsilon_{Bg} = 0.016$ for $\varepsilon_{Sg} = 0.9982$

Results – Efficiency

Events with angle η = 1.74 or θ = 20°
Given 1M muon and 1M pion simulation samples

Muon Efficiency: Muon to Muon = $\frac{N_{\mu\rightarrow\mu}}{N_{\mu}}$

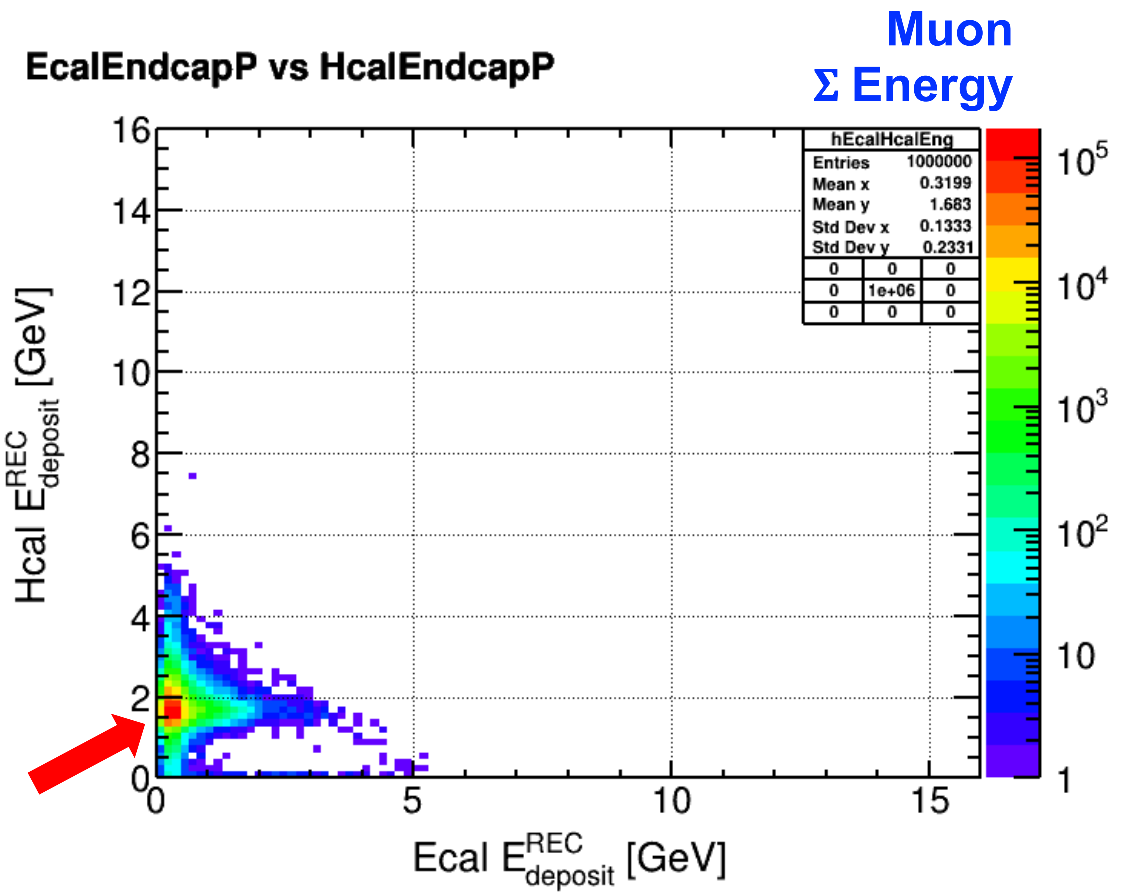
Background Rejection Efficiency: Pion to Pion = $\frac{N_{\pi\rightarrow\pi}}{N_{\pi}}$

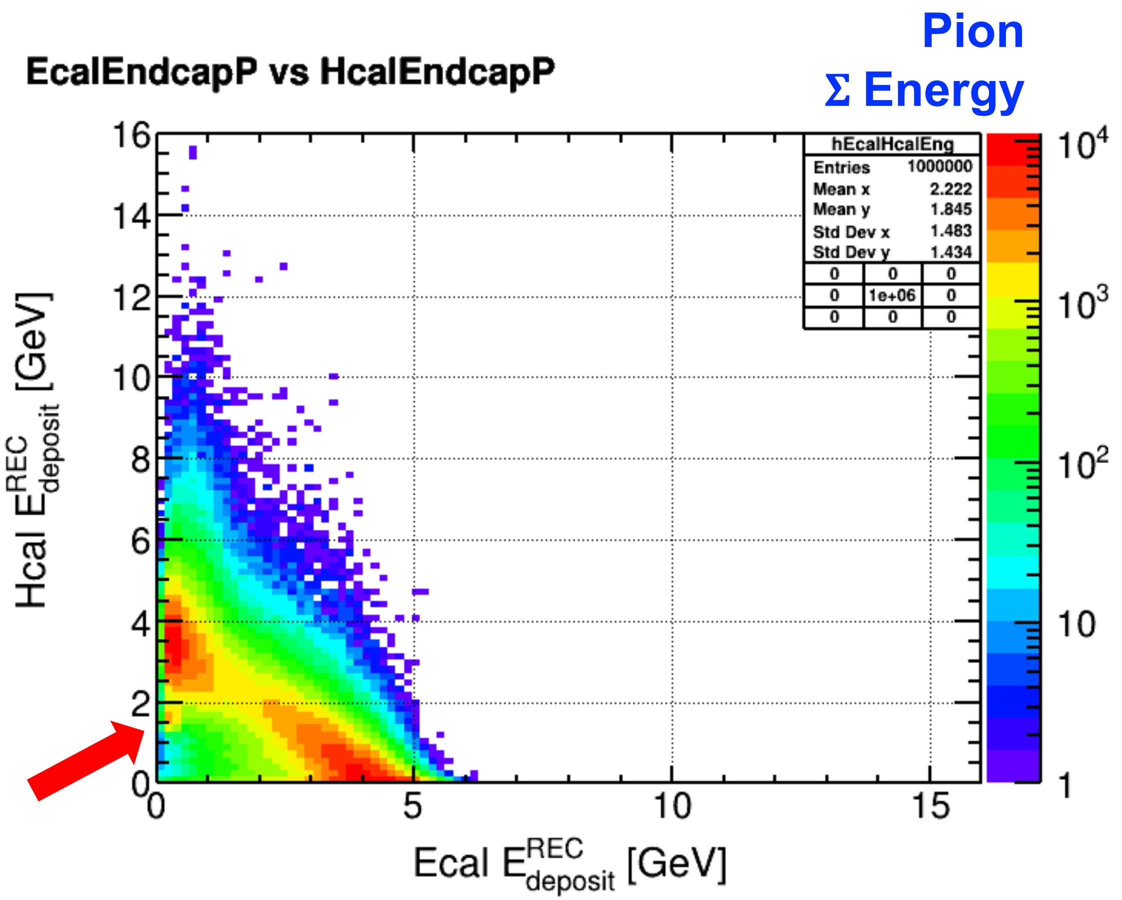
Mis-ID Efficiency: Pion to Muon = $\frac{N_{\pi\rightarrow\mu}}{N_{\pi}}$

Momentum [GeV/c]	Muon Efficiency		Background Rejection Efficiency		Mis-ID Efficiency	
1	0.607108	**0.752747**	0.968002	**0.962042**	0.031998	**0.037958**
2	0.9904	**0.987315**	0.986889	**0.987468**	0.013111	**0.012532**
5	0.996242	**0.997934**	0.982436	**0.984391**	0.017564	**0.015609**
10	0.995968	**0.997733**	0.9897	**0.990938**	0.0103	**0.009062**

p = 5 GeV and η = 1.74

Reconstructed ΣEnergy in Forward





While muon sample has one hot spot, pion sample has three groups;
pions showering from ECAL, pions showering from HCAL, and pions not showering at all (MIP-like)

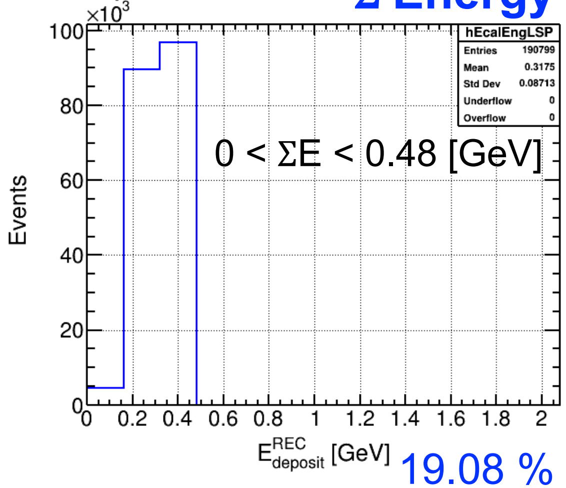
p = 5 GeV and η = 1.74

Pion Sample – Σ Energy

MIP-like in ECAL

Σ Energy

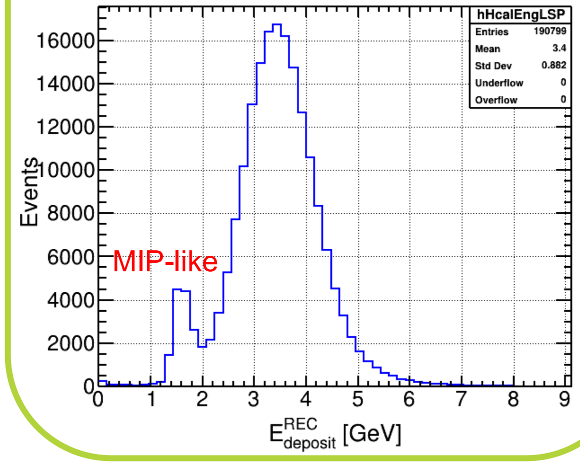
EcalEndcapP



19.08 %

mis-ID efficiency

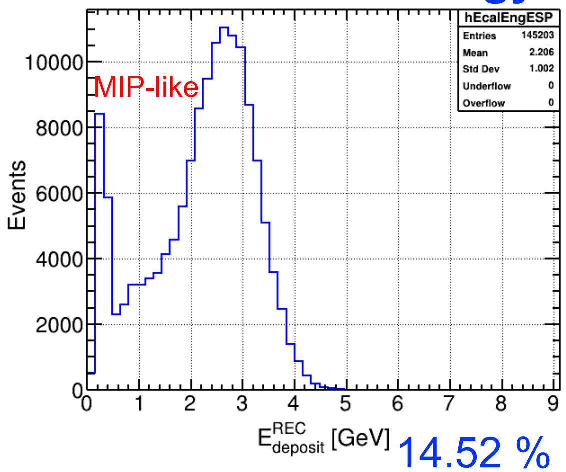
HcalEndcapP



MIP-like in HCAL

Σ Energy

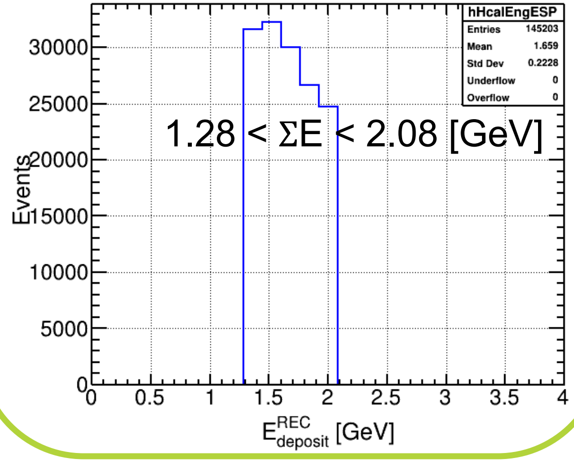
EcalEndcapP



14.52 %

mis-ID efficiency

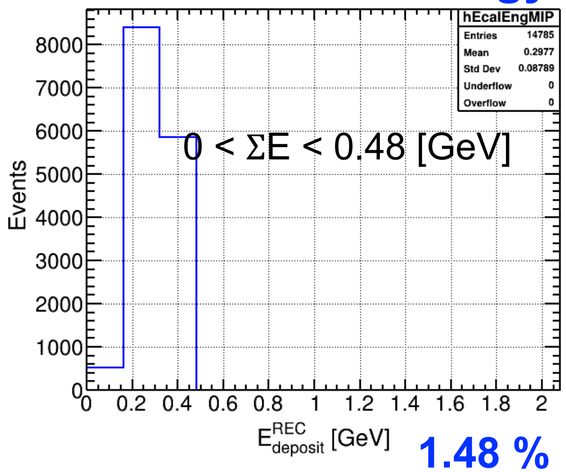
HcalEndcapP



MIP-like in ECAL & HCAL

Σ Energy

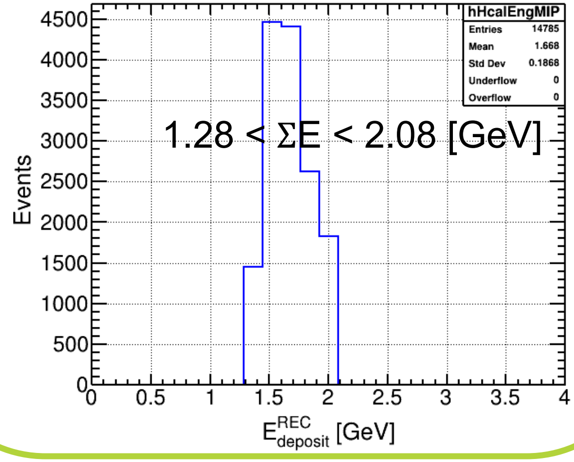
EcalEndcapP



1.48 %

mis-ID efficiency

HcalEndcapP



Results – With Cross Section

Events with angle η = 1.74 or θ = 20°
Given cross section from PYTHIA

Calculate **mis-ID rate** with **PYTHIA cross section**

Mis-ID Rate = $\frac{\{(N_{\pi\rightarrow\mu})*(\text{cross section})\}}{N_{\mu\rightarrow\mu}+\{(N_{\pi\rightarrow\mu})*(\text{cross section})\}}$

Momentum [GeV/c]	Muon Efficiency		Background Rejection Efficiency		Mis-ID Rate	
1	0.607108	0.752747	0.968002	0.962042	0.96344068	**0.96185097**
2	0.9904	0.987315	0.986889	0.987468	0.84280251	**0.83715130**
5	0.996242	0.997934	0.982436	0.984391	0.85774332	**0.84250306**
10	0.995968	0.997733	0.9897	0.990938	0.71783755	**0.69081573**

Summary

*Hard Exclusive Meson Production (HEMP)
**Timelike Compton Scattering (TCS)
***Double Deep Virtual Compton Scattering (DDVCS)

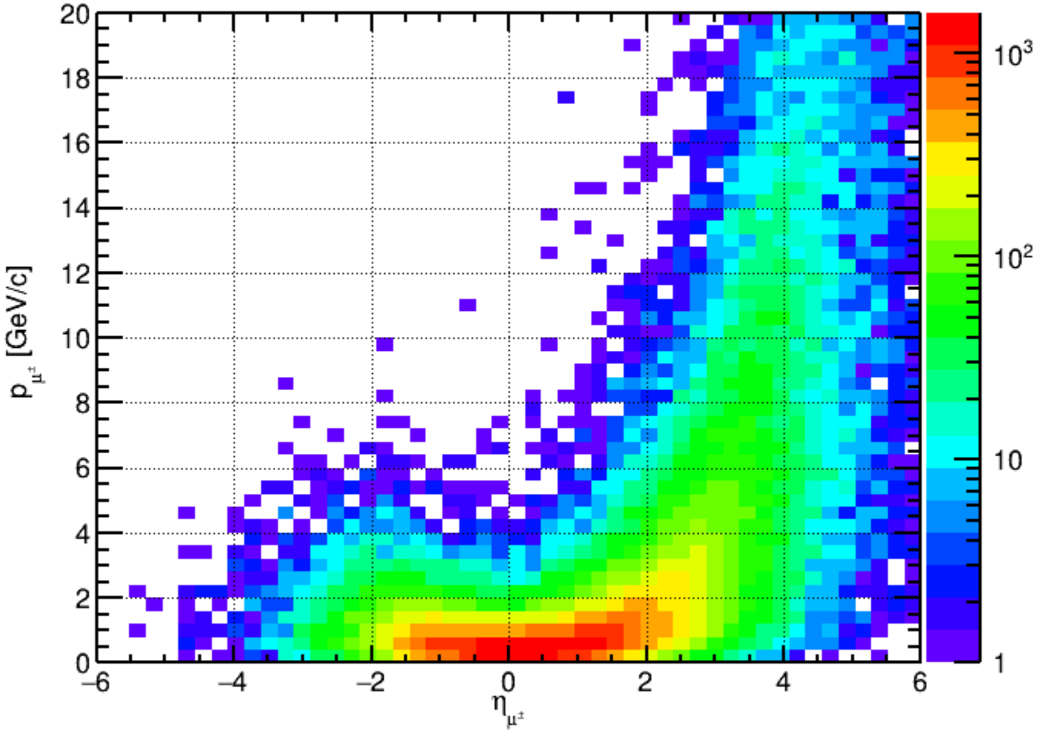
- In forward region (hadron-going),
  - Pair reconstruction such as $J/\psi \rightarrow \mu^{+}\mu^{-}$ may have better chance on reducing background (invariant mass): *HEMP
  - Single muon detection may be difficult, or
  - Other channels: **TCS, ***DDVCS, … (mass should not be in meson resonances?)
- Question: what physics needs muon detection?
  - Potential BSM Physics: Charged Lepton Flavor Violation $ep \rightarrow \tau/\mu\ X$
  - Promising ID channel: $\tau \rightarrow \mu\overline{\nu_{\mu}}\nu_{\tau}$: Larger branching ratio ~17%, suppression of SM background → Momentum or Kinematics of muons?
- To-Do List: there might be room for improvement
  - PID: do a back-of-the-envelope calculation with typical time/angle resolutions to check if muons/pions can be identified
  - Calorimeter Depth: interaction length check

Backup Slides

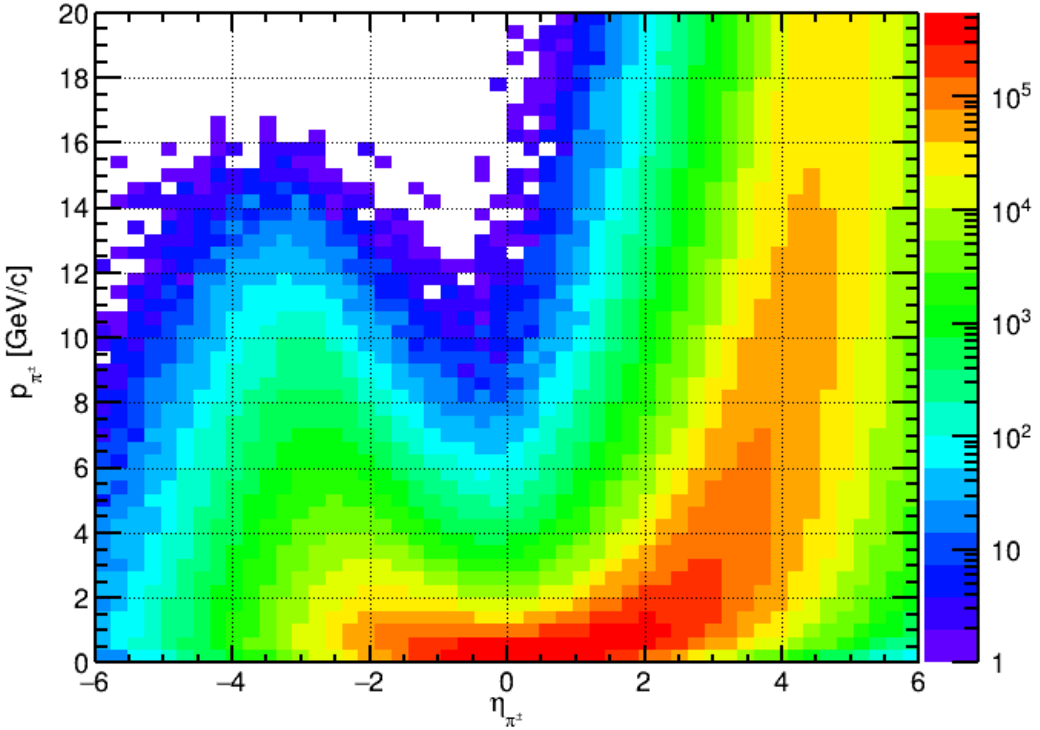
ep 18×275 GeV² 10M in high divergence mode (EIC CDR Table 3.3)

Cross Section from PYTHIA Sample

$\mu^{\pm}$



$\pi^{\pm}$



η = 1.74	1 GeV/c	2 GeV/c	5 GeV/c	10 GeV/c
N_{μ}	736	271	22	2
N_{π}	368039	109691	7507	492
N_{π}/N_{μ}	~ 500	~ 405	~ 342	~ 246

https://indico.bnl.gov/event/24891/contributions/96845/attachments/58675/100780/Experimental%20Overview%20of%20ePIC%20for%20BSM_Mike_Nycz.pdf

"Experimental Overview of ePIC for BSM" by Michael Nycz
From Uncovering New Laws of Nature at the EIC workshop Nov 20 -22, 2024

Charged Lepton Flavor Violation: **Decay Channel(s)**

1 Prong

$$\tau \rightarrow \mu \bar{\nu}_{\mu} \nu_{\tau}$$

1. Larger branching ratio ~ 17%
2. Suppression of SM background
3. Needs (good) μ identification

3 Prong (from $e \rightarrow \tau$)

$$\tau \rightarrow \pi^{-} \pi^{+} \pi^{-} \nu_{\tau}$$

1. Identification is easier than 1 prong channel

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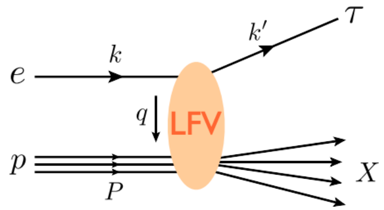
EIC Analysis



- Cross sections : $\mathcal{O}(1-10)$ pb at $\sqrt{S} = 141$ GeV

  e.g., 19 pb for $[C_{Lu}]_{uu}$ and 0.8 pb for $[C_{Ld}]_{bb}$

- Major backgrounds 1) Neutral Current $ep \to ej$

  2) Charged Current $ep \to \nu_e j$

- Promising ID channel

$$BR(\tau \to e\bar{\nu}_e\nu_\tau) = 17.82\,\%$$

✔ $$BR(\tau \to \mu\bar{\nu}_\mu\nu_\tau) = 17.39\,\%$$

$$BR(\tau \to X_h\nu_\tau) = 64.8\,\%$$

* Eliminate SM backgrounds

$$p_T^\mu > 10 \text{ GeV}, \ \ E_T > 15 \text{ GeV}, \ \ p_T^{j_1} > 20 \text{ GeV}$$

Made by E. Mereghetti